

Optimizing Pickling Cucumber Multi-environment Trials for Current and Future Challenging Growing Conditions

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Introduction

Multi-environment trials (METs) are essential in a breeding program to identify high-performing and stable genotypes across different environments (Costa-Neto et al., 2021). However, trial sites are often chosen based on convenience rather than representativeness, leading to reduced relevance to actual grower environments and inefficient resource use (Prado et al., 2024). In this context, this study proposes a data-driven framework to optimize MET site selection for U.S. pickling cucumber breeding under both current and future climate scenarios.

Material and Methods

For this analysis, we integrated multi-location and multi-year historical yield data with 235 environmental covariates (ECs) derived from 16 years (2010–2025) of NASA POWER weather data (Costa-Neto et al., 2021). Then, as in Prado et al. (2024), we used stepwise regression to identify 14 key ECs, accounting for approximately 88% of the yield variation across environments and years (four were soil variables, and the rest were mainly temperature and solar radiation during early crop stages). These ECs were then used to cluster (K-means) the 11 major cucumber-producing counties (accounting for 95% of the USA pickling cucumber production) into three distinct mega-environments (clusters) depicted on the left side of Figure 1. Finally, to evaluate the resilience of these sites under future growing conditions, we followed Fradgley et al. (2024) by comparing present-day environmental clusters with projections for two future planting windows: March-June 2050-2065 and April-July 2050-2065.

Results and Discussion

The comparative analysis revealed that nine of the 11 counties are likely to remain environmentally similar in the future while San Joaquin County (CA) and Arenac County (MI) may experience unique climatic shifts (Figure 1). Despite these shifts, our analysis confirmed that the same optimized set of counties would remain representative across both present and future production scenarios. Trial optimization (one trial per cluster, the one with the highest heritability) reduced the number of sites by 57% (from 7 to 3) while maintaining 100% representativeness of production zones and maintaining high Cullis heritability of 0.98 for yield. These results should improve the efficiency of cucumber breeding programs, reduce costs, increase accuracy, and align field evaluations with current and future farmer needs.

Acknowledgments

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Literature cited

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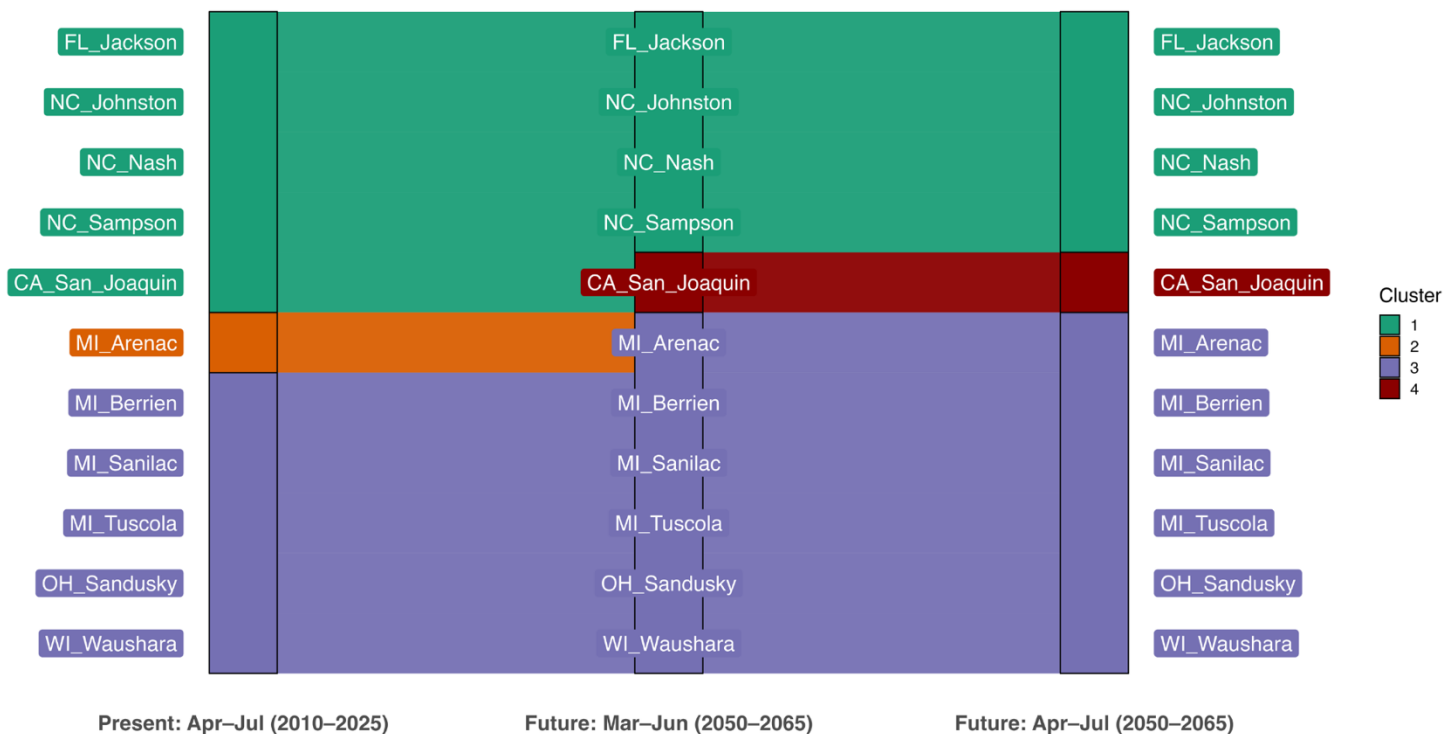


Figure 1. Predicted temporal progression of the mega-environments regarding the USA cucumber production and breeding. On the left, we have the present scenario based on average environmental data from 2010 to 2025. In the middle and on the right, respectively, we see an early planting scenario (March to June) and a normal planting scenario (April-July) predicted for 2050-2065. The flow paths show how counties shift between clusters. Most stay stable, but some move to different clusters as the environment changes. FL, Florida; NC, North Carolina; CA, California; MI, Michigan; OH, Ohio; WI, Wisconsin.